Lawrence Livermore Laboratory

TECHNOLOGY TRAINING PROGRAM

TRANSFERRING THE TECHNOLOGY OF WELDING AND BONDING—
HANDS-ON COURSES AT LLL MAKE IT POSSIBLE

C.W. Jensen and C.E. Hugenberg

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MASTER

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FOREWORD

This is the second in a series of reports about the Technology Training Program (TTP) presented by LLL during FY75-76. The first report, UCID-17060 by L. R. Zevanove, described the program and training facilities, using examples taken mainly from TTP course number 1, "Microprocessor Technology and Applications." To show a measure of training effectiveness, the results of questionnaires filled out by students were summarized for that class as well as courses 2 ("Digital Logic and Applications") and 3 ("Joining and Fastening").

This (interim) report delineates courses 4 and 5--"Welding and Bonding Technology"--and alludes to course 3, a similar presentation entitled "Joining and Fastening." The report supplements UCID-17060 by bringing in additional welding and bonding information. Although these two reports cover a certain amount of common ground, both should be read to gain a full understanding of the scope of the Technology Training Program.

The two reports contain information that will be treated more fully in a forthcoming implementation report which will present some practical results of the TTP courses (i.e., concrete results of the training, including case histories of specific individuals and organizations that benefitted and to what degree).

CONTENTS

The TTP Goal Restated	1
Orientation--Getting Acquainted	1
TTP Organization and Teaching Staff	4
Facilities, Methods and Equipment	6
Participating Government Agencies and Private Companies	10
Attendees: Technicians, Engineers, Others	11
Joining-Fastening and Welding-Bonding-- Five Busy Days of Intensive Training	12
Student Selection Process and Measuring Training Effectiveness--A Summary .	21
Acknowledgements	23
Appendix A: The Part-Time Teaching Staff for TTP Course Five	25
Appendix B: Glossary of Welding Terms	27
Appendix C: Dates and Titles of the First Five TTP Courses	31
Distribution	33

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C. W. Jensen
C. E. Hugenberger

TTP GOAL RESTATED

The ultimate goal of LLL's Technology Training Program is to transfer the Laboratory's unclassified technologies into the marketplace for the benefit of the community. As the Program's Head, L. R. Zevanove puts it: "Our goal, for ERDA, is to train.....a number of government and private-industry employees whose present productivity and on-the-job-effectiveness (in energy related fields) would be enhanced by learning and applying certain unclassified technologies developed at LLL."*

Toward this end, even after TTP students return to their jobs, LLL strives to assist them in transferring the technology they learned to their home organizations--to help them apply their new knowledge in developing or improving products or processes that "reach out" into the community.

ORIENTATION--GETTING ACQUAINTED

At the opening session of each TTP course, representatives of the ERDA San Francisco Operations Office and LLL management take personal interest in establishing good rapport with class members (Figures 1 and 2). Typical of this special interest are short presentations by K. R. Williams, H. C. McDonald, L. R. Zevanove, and R. J. Wasley. Together, their talks describe the NSF/ERDA role in funding TTP, ERDA's plan for technology transfer, and LLL's part in implementing the actual training. They also brief the students on the unclassified portions of major research programs at the Laboratory.

During coffee breaks between video taped lecture sessions, some of these same individuals and LLL supervisors mix with attendees, encouraging the students to describe their work and tell how assignments at their "home" organizations are energy related. With each other, they explore the possibilities of implementing the TTP instruction when the students return to their jobs.

*L. R. Zevanove, *Hands-On Training Program Transfers LLL Skills to Government Agencies and Private Industries*, Lawrence Livermore Laboratory, Rept. UCID-17060 (1976).

Figure 1. At each TTP-course orientation, LLL and ERDA representatives explain what the program is all about. Clockwise from upper left are: H. C. McDonald, LLL Associate Director for Engineering Support, K. R. Williams, Special Assistant to the Manager, San Francisco Operations Office, ERDA; L. R. Zevanove, Head of TTP, and R. J. Wasley, LLL Mechanical Engineering Department representative.

Figure 2. During informal discussions, TTP team members often learn about problems confronting students on their full-time jobs. LLL representatives often follow up to help bring about actual technology transfer.

Using this communicative approach in a semi-social atmosphere, LLL management has gained insight into both present and potential energy-related problems that, otherwise, would have gone unnoticed--problems for which LLL can help find solutions. For example, LLL learned of:

- The inability of Bay Area Rapid Transit (BART) employees to effectively clean and then weld aluminum compressor castings and anodized-aluminum hydraulic reservoirs
- The technical problems of California Department of Water Resources (DWR) welders inside 11-foot-diameter water pipes as they weld-fill holes eroded in the surfaces of huge pump-impeller blades.
- The tough decisions faced by East Bay Municipal Utility District (EBMUD) engineers in deciding whether to reweld (repair) or replace 86 miles of 5-foot-diameter pipeline originally installed in the 1920s.

The solution to these and other energy-related problems will be described in a forthcoming TTP implementation report telling how the TTP has leveraged its training processes to achieve technology transfer.

TTP ORGANIZATION AND TEACHING STAFF

Figure 3 shows how TTP fits into the overall LLL organization. The number "3.5" under TTP STAFF indicates the average full-time equivalent charges by the five staff members. Numbers "48" and "44" under ELECTRONICS and MECHANICAL ENGINEERING, respectively, denote the numbers of individuals who serve on the part-time teaching staff. Instructors are selected based on their expertise and ability to convey knowledge to others. (Instructors for course 5, "Welding & Bonding Technology," are listed in Appendix A.) During the one- and two-week courses, typical TTP involvement may be from one or two hours (lecturers) to one or more days (hands-on welding instructors). Still others may serve as guides during evening tours or man exhibits to explain, for example, how materials can be inspected for flaws and cracks using nondestructive test instruments (See Figures 4 through 7).

Figure 3. Simplified LLL organization chart shows how the Electronics and Mechanical Engineering Departments, under Associate Director H. C. McDonald, staff the Technology Training Program. Also shown is TTP's interaction with the San Francisco Operations Office of the Energy Research and Development Administration.

Figure 4. The part-time teaching staff includes lecturers who present their subjects in one or two hours.

Figure 5. A welding instructor (like the one demonstrating torch adjustments above) may work directly with students during hands-on sessions for one or more days.

Figure 6. During the joining-fastening and welding-bonding courses, several M. E. Department employees act as evening tour guides.

Figure 7. A Nondestructive Test Section employee demonstrates how transducers map the surface of materials bonded to a substrate. This is one of the recently developed ultrasonic methods for measuring the thickness of thin layers and the quality of bonding.

FACILITIES, METHODS AND EQUIPMENT

Facilities for the joining-fastening and welding-bonding courses include the open-bay trailer modules, where lectures are presented, and a laboratory several hundred feet away, where welding booths have been installed complete with an exhaust-ventilating system and temporary power (see Figures 8 and 9).

As an example of how facilities and teaching methods are evaluated and improved, movies and pictures of acoustic-emission techniques--a method of examining a weld during the welding process--were shown to students in the joining-fastening course. Now, in the welding-bonding courses, acoustic-emission test equipment is actually brought to the welding booths so students not only operate the equipment, they can evaluate their work as they weld.

Since the joining-fastening course was presented, the TTP staff has improved the welding facility in yet another way. A pulsed, arc-welding machine is brought in temporarily so students can observe and practice welding with this new technique that allows the operator to weld deep narrow grooves. (For definitions of welding processes, see "Glossary of Welding Terms," Appendix B.)

Another recent improvement is to bring in conversion equipment for the "standard" Miller stick-welding machines located in six of the eight welding booths. Installed in about two hours, this conversion equipment changes the arc welders to TIG-type machines (Tungsten Inert Gas) and provides instructors with an added flexibility.

Figure 8. Each of eight welding booths provides a work station for an instructor and three to four students. Temporarily installed welding equipment is converted, when needed, to the TIG process. Other welding machines give students hands-on experience with the MIG and new pulsed-arc processes.

Figure 9. Portable diesel units--standbys for scheduled LLL plant power shut-downs--are moved temporarily to near the welding area where they supply 480-volt, 50-amp, three-phase power to each welding station.

Thus, TTP students gain experience in a number of types of welding--stick, MIG, pulsed-arc and TIG processes.

Inside the lecture "hall" students study the subject in great detail by looking at TV monitors displaying the instructor's photomicrographs of welded metals. This medium of instruction lends itself particularly well to teaching students how to join materials together (Figure 10).

Since UCID-17060 was published, the lighting, audio, and video capabilities at the TTP facility have been improved. Originally designed as a portable audio and video monitor, the vertical-rack console (Figure 11) has served temporarily as a switcher, also. Now, the entire unit has been replaced with the sloping-panel console shown in Figure 12. At these new controls, the operator not only can switch cameras, she can control a number of video functions to optimize picture quality--a capability not available in the previous system (Figure 13).

Figure 10. Live instruction with TV monitors in the classroom provide excellent means of teaching joining-fastening and welding-bonding courses because, for example, the overhead TV camera and monitoring system can display photomicrographs of grain structures and flaws in welded materials.

Figure 11. A view of the instructor's podium and the classroom from the corner shows the vertical construction of the old TV control panels, now replaced with the new console at right.

Figure 12. In this new TV console, all necessary functions are designed into a cohesive system that provides controls for all cameras--a considerable improvement over the old system comprising individual portable units.

Figure 13. An example of the video signal and picture from each camera that is now controlled from the new TV console.

PARTICIPATING GOVERNMENT AGENCIES AND PRIVATE COMPANIES

Government agencies and private companies taking part in the first five TTP courses are shown in Table 1. The increase in the number of organizations is:

	THROUGH TTP COURSE 3 (Joining and Fastening)	THROUGH TTP COURSE 5 (Welding and Bonding)
ERDA RELATED	7	7
OTHER FEDERAL, STATE AND MUNICIPAL AGENCIES	18	23
PRIVATE INDUSTRY, NON- PROFIT FOUNDATIONS, EDUCATIONAL INSTITUTIONS	7	23
TOTAL REPRESENTED	32	53

Table 1. Participating Government Agencies and Private Companies

<u>ERDA RELATED</u>	
E. G. & G. INCORPORATED	SANDIA LABORATORIES
FERMI NATIONAL ACCELERATOR LABORATORY	STANFORD LINEAR ACCELERATOR CENTER
HANFORD ENGINEERING DEVELOPMENT LABORATORY	UNIVERSITY OF CALIFORNIA, LBL
MONSANTO RESEARCH CORPORATION	
<u>OTHER FEDERAL, STATE AND MUNICIPAL AGENCIES</u>	
BAY AREA RAPID TRANSIT DISTRICT	CITY OF SAN JOSE
BUREAU OF RECLAMATION	CITY OF SUNNYVALE
CALIFORNIA DEPARTMENT OF TRANSPORTATION	EAST BAY MUNICIPAL UTILITY DISTRICT
CALIFORNIA DEPARTMENT OF WATER RESOURCES	FEDERAL AVIATION ADMINISTRATION
CALIFORNIA DIVISION OF COMMUNICATION	HIGHLAND GENERAL HOSPITAL
COAST GUARD	MARE ISLAND NAVAL SHIPYARD
CORPS OF ENGINEERS, U.S.A.	NAS ALAMEDA
CITY OF ANAHEIM	ORO LOMA SANITARY DISTRICT
CITY OF HAYWARD	SAN BRUNO WASTE TREATMENT PLANT
CITY OF LIVERMORE	UNION SANITARY DISTRICT
CITY OF PALO ALTO	VALLEJO SANITARY & FLOOD CONTROL
CITY OF RICHMOND	
<u>PRIVATE INDUSTRY, NON-PROFIT FOUNDATION, EDUCATIONAL INSTITUTIONS</u>	
CALIFORNIA ELECTRIC COMPANY	MOLY-CORPORATION INCORPORATED
CHABOT COLLEGE	PACIFIC GAS & ELECTRIC COMPANY
EATON CORPORATION	PACIFIC OXYGEN COMPANY
ELBY MANUFACTURING COMPANY	PARKER-HANNIFIN
FAB-MACH INCORPORATED	PHILLIPS PETROLEUM CORPORATION
FREMONT UNION HIGH SCHOOL DISTRICT	STANDARD OIL COMPANY
GENERAL ELECTRIC COMPANY	THERMIONICS LABORATORY INCORPORATED
HOBART PACIFIC WELDERS	UNITED STATES STEEL COMPANY
KAISER ALUMINUM & CHEMICAL CORPORATION	UNION CARBIDE CORPORATION
KAISER PERMANENTE HOSPITALS	VICTOR WELDING EQUIPMENT COMPANY
LIVERMORE PRECISION MACHINE WORKS	WEST TEXAS STATE TECHNICAL INSTITUTE
LOVELACE MEDICAL FOUNDATION	

ATTENDEES: TECHNICIANS, ENGINEERS, OTHERS

Figure 14 shows the number of applicants, the number of acceptances and the technicians/engineers/others percentage ratio of those who attended courses 3, 4, and 5. Figure 15 combines and summarizes these data for all of the first five TTP courses. Of all the students attending these classes, 72% were technicians, 17% were engineers, and 11% were in the "Others" category (e.g., business owner, engineering manager, supervisor, programmer, medical doctor, and Coast Guard officer). The number of affirmative-action participants has been approximately 20%.

JOINING AND FASTENING (COURSE 3)

88% TECHNICIANS

12% ENGINEERS

87 CANDIDATES
28 ACCEPTED

WELDING AND BONDING (COURSE 4)

8% ENGINEERS

15% OTHERS

77% TECHNICIANS

70 CANDIDATES
26 ACCEPTED

WELDING AND BONDING (COURSE 5)

27% ENGINEERS

15% OTHERS

58% TECHNICIANS

57 CANDIDATES
26 ACCEPTED

Figure 14. Summary of applications and acceptances for TTP courses 3, 4, and 5. The "Others" category includes business owner, engineering manager, supervisor, programmer, medical doctor, and Coast Guard officer.

COURSES 1 THRU 5

Figure 15. Total students attending the first five classes. A list of the course titles and dates is shown in Appendix C.

JOINING-FASTENING AND WELDING-BONDING TECHNOLOGY-- FIVE BUSY DAYS OF INTENSIVE TRAINING

Monday

The first of the five busy days starts with registration. Students are issued red temporary LLL badges and escorted to the TTP trailer complex. The program opens with short indoctrination talks by members of LLL management, the TTP staff, and a representative from the San Francisco Operations Office of the Energy Research and Development Administration (see Figure 1). These introductory talks are followed by a lecture/demonstration about the hazards and toxicity of the materials with which students will be in contact--both during the TTP course and back on their jobs.

The course material builds upon the foundation which most students have and, therefore, the first afternoon begins with oxyacetylene welding. However, to counteract feelings of "I've had this before," the TTP curriculum planners precede this subject with a lecture and hands-on laboratory entitled "Polymeric Materials." A second lecture/demonstration describes and shows samples of plastic composites. While most students are aware of the increased number of products manufactured from plastics over the last 20 to 25 years, few are familiar with the properties of these new materials. Therefore, many students are surprised to learn that certain plastics have properties superior to those of steel. By relating to students' sports items (e.g., skis, golf clubs, fish poles and boats), many of which are produced from plastics, instructors capture the student's interest the first morning.

The afternoon oxyacetylene lecture describes how welding torches operate, the hazards involved, metal preparation, and the materials that can be cut, welded, soldered or brazed by this method. While many of the students are familiar with these subjects, the hands-on laboratory gives them the chance to improve their torch-welding skill.

Thus, by "playing it loose" the first day--relating to student's hobbies and building on previous knowledge--TTP instructors and others try to bridge the communications gap and build an atmosphere of free and open discussion (see Figure 2). Examples of first-day activities are shown in Figures 16 through 21.

Figure 16. Gaining experience with a hot air torch, students learn to bond plastic sections together.

Figure 17. This ultrasonic welder is used to join mylar pieces.

Figure 18. On tour, students see this LLL designed four-axis filament-winding machine

Figure 19. Wound from Kevlar on the machine at the left, this composite reinforced pressure vessel, fabricated for NASA, shows TTP students one advanced use for plastics.

Figure 20. Instructors demonstrate methods of oxyacetylene welding and brazing.

Figure 21. Students are shown examples to follow--how a good braze has dissolved the filler into the parent metal.

Tuesday

During the Tuesday-morning sessions, instructors review the first day's subjects and students conclude their study of torch welding as they concentrate on improving their techniques wherever they have problems.

At the afternoon lectures and laboratory classes, instructors describe the "standard" arc-welding and TIG-type equipment; then, they brief students on the projects they are to weld. In the laboratory, where some of the "standard" welders are converted to TIG-type machines, students then practice adjusting equipment power output for optimum welds as they complete the tasks assigned to them (see Figure 22).

Figure 22. Instructors demonstrate and students practice the proper methods of holding and steadily guiding the "stick" and the TIG welding torch.

On-the-spot inspection by instructors helps students improve their technique and immediately correct mistakes in their practice welds.

A student (left) learns the technique of welding butt-jointed thin sheets of stainless steel. The assembly is bolted down with heat sinks that prevent overheating and distortion.

In the evening, students are toured through LLL's welding facilities. Examples of equipment being demonstrated, or which students operate themselves, include plasma-arc profiling and laser-welding apparatus, glove boxes with controlled atmospheres in which to weld, electronic beam welding machines, precision welding fixtures, and other specialized equipment. Some of this equipment is shown in Figure 23.

Figure 23. On tour through the welding shops of the Materials Fabrication Division, TTP students observe deep penetration welds being made as they sit at the console of the electron-beam welder. Also, they see such advanced industrial "tools" as the laser-welding device shown at right.

Wednesday

The first two hours of the day are set aside for an arc-welding lecture that describes arc physics and the fusion process. Following this, students adjourn to the laboratory where they practice with "standard" welders, TIG-type machines, MIG equipment, and the pulsed-arc process. Some of these activities are shown in Figures 24 through 29. As this is an extended laboratory period lasting throughout the rest of the workday, a lecture about the structure of metals is interspersed for variety between the morning and afternoon sessions.

Figure 24. Increased complexity--students not only need a steady hand to hold the "torch" at the correct distance and angle; they need to control the turning speed of parts being welded in this rotating fixture.

Figure 25. Students practice the MIG-welding process of filling milled "V" grooves with weld--an effective technique to stimulate joining two pipe sections.

Figure 26. A close-up view of the pipe shows the "V" grooves and the quality of the welds. Note the numerous "pin-hole" flaws and blobs depicting poor welds as compared to the flat-weld fill in the fifth groove from the right.

Figure 27. When "standard" welding machines are converted to the TIG process, students learn to adjust the equipment for proper voltage and current, which results in optimum heat for a particular weld. Tungsten tips must also be adjusted.

Figure 28. Following the MIG (and other) welding processes, students practice chipping away the flux slag.

Figure 29. Gathered around the welding lathe, students learn by watching the welds being made as each takes a turn in practicing the TIG process.

On the Wednesday evening tour, an instructor describes and demonstrates the acoustic-emission technique--a method for instrumenting and evaluating a weld during the actual welding process. (see Figures 30 and 31).

Figure 30. An instructor explains what to look for on an acoustic-emission oscilloscope trace to indicate whether a weld is good or bad. After the demonstration, this equipment is set up temporarily in the TTP welding laboratory for students to have their work evaluated as they weld.

Figure 31. The transducer for various acoustic-emission instruments is attached directly to the material to be welded.

Thursday

By the fourth day, students have improved their "stick", MIG, and TIG welding techniques with steel and aluminum sufficiently to begin welding materials more difficult to bond.

To introduce students to these difficult-to-weld materials, an engineer from the Chemistry and Materials Science Welding Research Laboratory lectures on "special" materials (e.g., tantalum and various high-alloy steels) on which research is being conducted. (In contrast to the LLL welding shops of the Materials Fabrication Division, where standard welding techniques and materials are used, this group performs research on many of the metals thought to be "unbondable" by today's methods.)

Following this introduction, students take part in a four-hour extended laboratory session in which they practice such welding as copper-copper, copper-stainless steel, aluminum-stainless steel, and other dissimilar metals.

In the late afternoon and early evening, students attend a tour preceded by a lecture entitled "Advanced Joining Processes and Properties of Welds." This presentation gives the class an overview of high-energy-density welding systems and the bonding techniques used in laser-and electron-beam welding.

The tour of the Materials Science Welding Research Laboratory includes many demonstrations and the hands-on operation of electron beam welders (Figures 32 through 35).

Figure 32. Students learn the precision capabilities of electron-beam welders as they operate the controls and attain high-purity welds with minimum distortion. Metals such as tungsten and tantalum are welded here.

Figure 33. In a welding research laboratory, one necessary "universal" tool is a resistance spot welder--indispensable for making fixtures to hold materials to be welded.

Figure 34. TTP students hear an explanation about the automatic arc-gap control on the TIG welder at left. As the contour changes, the arc gap remains constant.

Figure 35. LLL instructor demonstrates how water-cooled coils, sized to fit a specimen, are operated at high frequencies to inductively heat and braze metals together.

Friday

During the final day of the joining-fastening and welding-bonding courses, students learn about ultrasonic, x-ray, and other welding-and bonding-inspection techniques at LLL. On a conducted tour, students see material flaw-detection equipment--some demonstrated--and they receive hands-on experience when they try state-of-the-art inspection methods for locating defects in materials and welds (Figures 36 through 39). Also, there is a two-hour period when, by prearrangement, students can return to an area of particular interest for further information.

Figure 36. Using an x-ray film illuminator and variable light source, TTP instructor points out weld defects in a student project. Typically, welding flaws include gas bubbles, slag inclusions, blow holes, and lack of weld penetration.

Figure 37. One of the TTP students, a community college welding instructor, operates an ultrasonic inspection system as he looks for flat-bottomed calibration holes predrilled in the opposite plate surface.

Figure 38. The huge 13-MEV x-ray machine with its 3000 R/minute beam detects flaws in steel 15-inches thick.

Figure 39. Students move ultrasonic transducers across the surfaces of stainless steel plates to locate flaws in the metal. Voids produce variations in oscilloscope patterns.

The course concludes with a critique session followed by a social hour when TTP staff members, instructors, LLL supervisors, and students meet informally to discuss the course and how the students plan to implement what they have learned. It is during this final gathering that many of the previous contacts are "solidified" and arrangements are made to visit the student's place of work to help implement the training received at LLL.

STUDENT SELECTION PROCESS AND MEASURING TRAINING EFFECTIVENESS--A SUMMARY

The TTP has established guidelines for choosing students and measuring the effectiveness of instruction. These procedures are outlined below. TTP staff members:

- locate organizations whose energy-related processes or products might be improved by adopting the LLL know-how
- interview applicants from these institutions; select the most qualified for TTP training
- evaluate student feedback questionnaires
- monitor requests for video tapes and other instructional material
- conduct a follow-up program to observe implementation

One of the above, an evaluation of the student feedback questionnaires, is shown on the pages that follow.

During each class, the students are asked to evaluate the course material with respect to their own background and knowledge. These student evaluations are studied by TTP staff members to see if the course contents or teaching methods should be altered to better meet the needs of the students.

As an example of this feedback, refer to Tables 2 and 3. These tables summarize student evaluations for each lecture and laboratory subject in courses 4 and 5.

Tables 2 and 3 show a general trend of improvement. Of the 13 lecture and laboratory sessions evaluated by the students, eight sessions showed the same or improved ratings for course 5 in the "Just Right" column, and one period, "Property of Welds" lecture (an added topic), had 100% "Just Right." For quick reference, these data are compared side by side in Table 4.

When asked to comment on this type of feedback, R. J. Wasley, TTP staff representative from the Mechanical Engineering Dept. said, "We can never hope, nor should we try, to have all student evaluations fall in the "Just Right" column. This is because each class is slightly different. What is too difficult for one may be too easy for another. This feedback does show, however, a high degree of acceptance (of course material) among the TTP students."

Table 2. Results of students' evaluation of TTP course 4, "Welding and Bonding Technology," showing each major-topic session.

PERCENTAGE OF RESPONDENTS VOTING THAT MATERIAL WAS:	TOO HEAVY	JUST RIGHT	TOO LIGHT
POLYMERIC MATERIAL LECTURE		100	
POLYMERIC MATERIAL LAB.		74	26
OXYACETYLENE LECTURES		81	19
OXYACETYLENE LABS.		64	36
PLASTIC COMPOSITES LECTURE		100	
ARC WELDING LECTURES	8	80	12
ARC WELDING LABS.		81	19
WELD TEST AND EVALUATION LECTURE		100	
LASER WELDING LECTURE	4	88	8
INSPECTION TECHNIQUES LECTURE	6	94	
ULTRASONIC INSPECTION LECTURE		100	
ULTRASONIC INSPECTION LAB.		90	10
OVERALL EVALUATION	1	89	10

Table 3. Results of students' evaluation of TTP course 5, "Welding and Bonding Technology," showing each major-topic session.

PERCENTAGE OF RESPONDENTS VOTING THAT MATERIAL WAS:	TOO HEAVY	JUST RIGHT	TOO LIGHT
POLYMERIC MATERIAL LECTURE	5	90	5
POLYMERIC MATERIAL LAB.		80	20
OXYACETYLENE LECTURES		95	5
OXYACETYLENE LABS.		68	32
PLASTIC COMPOSITES LECTURE	28	72	
ARC WELDING LECTURES	8	87	5
ARC WELDING LABS.		70	30
WELD TEST AND EVALUATION LECTURE		95	5
LASER WELDING LECTURE		100	
PROPERTY OF WELDS LECTURE		100	
INSPECTION TECHNIQUES LECTURE		100	
ULTRASONIC INSPECTION LECTURE		100	
ULTRASONIC INSPECTION LAB.		100	
OVERALL EVALUATION	3	89	8

Table 4. Students in TTP courses 4 and 5 evaluated each major-topic session. Here are the results, given side by side for comparison.

PERCENTAGE OF RESPONDENTS VOTING THAT MATERIAL WAS:	TOO HEAVY		JUST RIGHT		TOO LIGHT	
COURSE NUMBER	4	5	4	5	4	5
POLYMERIC MATERIAL LECTURE		5	100	90		5
POLYMERIC MATERIAL LAB.			74	80	26	20
OXYACETYLENE LECTURES			81	95	19	5
OXYACETYLENE LABS.			64	68	36	32
PLASTIC COMPOSITES LECTURE		28	100	72		
ARC WELDING LECTURES	8	8	80	87	12	5
ARC WELDING LAB.			81	70	19	30
WELD TEST AND EVALUATION LECTURE			100	95		5
LASER WELDING LECTURE	4		88	100	8	
*PROPERTY OF WELDS LECTURE				100		
INSPECTION TECHNIQUES LECTURE	6		94	100		
ULTRASONIC INSPECTION LECTURE			100	100		
ULTRASONIC INSPECTION LAB.			90	100	10	
OVERALL COURSES 4 & 5	1	3	89	89	10	8
OVERALL COMBINED	2		89		9	

*Curriculum change

L. R. Zevanove sums up his feeling about measuring training effectiveness: "While these course evaluations by the students are of benefit to our TTP staff, the real proof of our training effectiveness lies in knowing that the student's skill in a particular subject has improved. This can only be determined as we follow up these former students and their organizations to see how they are implementing the TTP training."

Over the past months, LLL staff members have maintained contact with former TTP students. The results of their findings are soon to be published in an implementation report. Also to appear in this series of reports for FY75-76 is a description of TTP course 6, "Microprocessor Technology and Applications."

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APPENDIX A:

WELDING & BONDING TECHNOLOGY

The Part-Time Teaching Staff for TTP Course Five

R. P. Althouse
J. R. Ambrosino
G. R. Baxter
N. W. Boyer
F. T. Bryan
A. L. Buerer
R. C. Buso
T. T. Chiao
C. W. Clift
G. A. Clough
D. W. Crawford
F. W. Drobnick

D. L. Dufek
H. G. Dyer
H. G. Hammon
M. A. Hampstad
C. L. Hansen
E. S. Jessop
H. V. Kirby
R. Louie
K. C. MacMillan
G. L. Mara
R. E. Niver
R. G. Patterson
E. M. Placas

P. J. Radich
E. A. Ratcliff
T. J. Ramos
C. L. Rowe
F. W. Silva
A. J. Schwarber
L. I. Talbot
L. M. Wagner
D. Webster
H. Weiss
E. F. Westland
C. N. Westrich

APPENDIX B:

GLOSSARY OF WELDING TERMS

Welding is the art or science of making a metallurgical joint with the desired properties between two or more pieces of metal by the proper application of heat and/or pressure.

Gas Welding--A welding process wherein the heat necessary for fusion is generated by the combustion of flammable gases--usually oxygen and acetylene--and transferred to the metal pieces to be joined by conduction. If metal is required to complete the joint, it must be added externally by hand or machine. No pressure is used directly in this process.

Electron Beam Welding--A welding process wherein the heat necessary for fusion is generated by the kinetic energy released when a stream of high voltage electrons strike the metals to be joined, in a vacuum chamber. The vacuum permits the electrons to travel over a long distance to join the metals, while at the same time preventing oxidation of the parts.

Fusion Welding--A welding process wherein a metallurgical joint between two pieces of metal is made by applying enough heat to melt the adjoining surfaces. Pressure may or may not be applied and extra metal may or may not be added.

MIG Welding--A welding process wherein the heat necessary for fusion is generated by an electric arc drawn between a rapidly moving wire and the metal pieces to be joined. The rapidly moving wire melts and supplies metal to fill the joint and an inert gas blankets the weld and protects the molten metal from oxidation. No pressure is used directly in the process.

Plasma-Arc Welding--A welding process wherein the heat necessary for fusion is generated by the passing of electric current through an ionized gas and with the gas flow subsequently constricted to give high gas velocities and a high concentration of heat. No pressure is used directly in the process.

Pulsed MIG (Metal Inert Gas) and Pulsed GMA (Gas Metal Arc)--A welding process wherein the welding current switches from one value to another. The lower-level current is the background current; the upper-level current is the pulsed-peak current. The pulse rate is normally 60 or 120 pulses per second, but it can be other frequencies that are usually higher. The detachment of the metal (metal transfer drop) optimizes during the pulse peak. The current, then, to make a weld is the average between low- and peak-level currents. Therefore, low heat input welds can be made with good arc stability.

Shielded Metal-Arc Welding--(also known as "stick" or "coated-electrode" welding)--A welding process wherein the heat necessary for fusion is generated by an electric arc drawn between a coated-metal rod and the metal pieces to be joined. The metal rod melts and provides metal to fill the joint, and the coating melts and forms a slag which protects the molten metal from oxidation. No pressure is used directly in the process.

Spot Welding--A welding process wherein the heat necessary for fusion is generated by the passing of a high amperage, low voltage, current through two pieces of metal to be joined. The contact resistance to the flow of current between the two pieces of metal causes heat to be generated at the contact point sufficient to melt a portion of each metal and bond them. Pressure is applied both to control the heat (by changing the contact resistance) and to contain the molten metal while it solidifies.

TIG Welding--A welding process wherein the heat necessary for fusion is generated by an electric arc drawn between an inert tungsten electrode and the metal pieces to be joined. An inert gas blankets the weld and protects the molten metal and the hot tungsten from oxidation. If metal is required to complete the joint, it must be added externally by hand or machine. No pressure is used directly in the process.

APPENDIX C:

DATES AND TITLES OF THE FIRST FIVE TTP COURSES OFFERED DURING FY75-76

SEPTEMBER 22 - OCTOBER 3, 1975	MICROPROCESSOR TECHNOLOGY AND APPLICATIONS
OCTOBER 28 - NOVEMBER 7, 1975	DIGITAL TECHNOLOGY AND APPLICATIONS
DECEMBER 8 - 12, 1975	JOINING AND FASTENING TECHNOLOGY
MARCH 8 - 12, 1976	WELDING AND BONDING TECHNOLOGY
APRIL 12 - 16, 1976	WELDING AND BONDING TECHNOLOGY

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Technical Information Department

LAWRENCE LIVERMORE LABORATORY

University of California | Livermore, California | 94550